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FOREST INSECT INVESTIGATIONS

REPORT ON THE INSECT SITUATION AND EXPERIMENTS IN THE NEBRASKA NATIONAL FOREST DURING 1933

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Forest Insect Laboratory,
Coeur d'Alene, Idaho,
Sept. 20, 1934

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Respectfully submitted,

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REPORT ON THE INSECT SITUATION AND EXPERIMENTS IN THE NEBRASKA NATIONAL FOREST DURING 1933

This report records observations made on injurious insects during 1933 in the pine plantations and nursery which comprise the Nebraska National Forest near Halsey, Nebraska, including the results from certain control experiments. Most of the season from early April to November was spent on this project, with several short periods given to the investigation of insect infestations in other forests of Forest Service Region 2.

This report covers observations on the infestation of the two species of pine tip moths; studies on parasitism of the original species, *Rhyacionia frustrana bushnelli* (Busck), including the progress of the introduced parasite, *Campoplex frustranae* Cush.; and notes on the life history of the more recent tip moth, *R. neomexicana* (Dyar), including records of its additional spread and increase in the plantations. The results from experimental dipping and spraying for the egg stage of *R. neomexicana* are also given. The discussion on the pitch moth, *Dioryctria ponderosae* Dyar, includes additional life history notes; results from spraying with Orthene (orthodichlorobenzene) for the larval and pupal stage; and the status of the infestation as indicated by tree plot records. The white grub experiments show the effect of different strengths of lead arsenate treated soil on pine transplant stock in the nursery. Notes on the grasshopper infestation and bark beetles close the report.

Last year two reports were submitted, one covering the pitch moth situation, the other dealing with the tip moths and other insects. These two reports not only covered the 1932 observations but reviewed some of the earlier data and summarized the tree plot records. These data will not be repeated in the present report except where the 1933 conditions are compared to the previous year.

THE PINE TIP MOTHS

To clarify the pine tip moth situation, mention should first be made of the present uneven distribution of the two species in the plantations. The more recent and single generation species, _Rhyacionia neomexicana_, which has become destructive within the last five years, started in the older plantations in the northeast part of the planted area, near the nursery, and at present is causing serious damage within a radius of about 2 to 2½ miles from the nursery. The original two generations species, _R. bushnelli_, was reduced to low numbers in most of this same area several years ago by the introduced parasite and has not again built up to its original population. However, in the outlying plantations, roughly from 3 to 5 miles from the nursery, _bushnelli_ is still the important species, the population fluctuating annually with the abundance of the introduced parasite. Consequently at present _R. neomexicana_ is the more destructive species in the older plantations, while _R. bushnelli_ is still the important species in the younger and outlying plantations.

The introduced parasite, Campoplex frustranae, is apparently unable to develop in the larvae of the recently destructive tip moth, Rhyacionia neomexicana. There is some evidence, however, that it may oviposit in the young larvae of this moth in the spring when both species of moths are present, which would tend to have a detrimental effect on the abundance of the parasite from this generation. During the second generation Campoplex is free to attack its normal host alone, as R. neomexicana has but the single spring generation annually.

There is also a question as to the effect of competition between the larvae of the two species of moths where they occur in the same tips. In the area where neomexicana is now by far the most abundant species the other moth has failed to show any great increase in the last two years. This is undoubtedly due partly to continued parasitism, although the per cent of parasitism of the first generation has not been high. It also seems possible that where many neomexicana larvae occur in a pine shoot with only one or two of the somewhat smaller bushnelli larvae the latter may be at a disadvantage. In such an event the increased population of neomexicana would in time influence the abundance of the original bushnelli. Aside from the case mentioned above there is little evidence of this influence from competition, but more information on this point may be gained as neomexicana spreads into the younger plantations where bushnelli is abundant.

The tip moth infestation in 1933 was in general heavier than in 1932, as indicated by a check of four permanent tree plots in ponderosa and Norway pine. These plot data are presented in Table I. In two of the plots there was a considerable increase; in one case, in Norway pine Plot No. 20, due largely to the building up of Rhyacionia neomexicana in the area as well as to an increase of the other moth. In the other case, in ponderosa pine Plot No. 1, in an outlying plantation near Camp 3, the increase was due to the multiplication of the second generation of R. bushnelli, following a marked drop in parasitism from the previous year.

TABLE I
HEIGHT GROWTH OF TREES AND PERCENT OF LEADERS INFESTED BY PINE TIP MOTHS IN PONDEROSA AND NORWAY PINE PLOTS, 1932 AND 1933. EACH PLOT CONTAINS FROM 96 TO 100 TREES

Year	Aver. Ht. of trees in inches	Increase in Ht. over previous year	% leaders inf. by one or both species	% inf. by R. bush.	% additional inf. by R. neomex.*
	Ponderosa pine Plot No. 19 (planted 1915)				
1932	87.4	6.8	91	26	65
1933	94.5	7.1	95	28	67
	~~Ponderosa~~ Norway pine Plot No. 20 (planted 1915)				
1932	86.9	15.0	57	48	9
1933	102.0	15.1	91	68	23
	Ponderosa pine Plot No. 13 (planted 1918)				
1932	65.1	5.7	91	67	24
1933	73.9	8.8	96	62	34
	Ponderosa pine Plot No. 1 (planted 1924)				
1932	27.0	1.8	59	59	0
1933	37.2	10.2	97	96	1

*(The last column does not show the full amount of R. neomexicana infestation, as some of the tips recorded under R. bushnelli were also infested by this species; however, it indicates how much the original infestation by bushnelli has been increased by the presence of this more recent species).

In regard to tree growth, as shown in Table I, most of the plots had an increase in 1933 over 1932, due partly to a more favorable growing season. However, growth is largely dependent on the number of leaders injured the previous year. The greatest increase in height growth was made in ponderosa pine Plot No. 1, where 41% of the leaders were uninfested in 1932, due to high parasitism of R. bushnelli that year, and ready for normal growth the following spring. The average of 10.2 inches in 1933 represents an increase of 467% in height growth over 1932, and is nearly twice the growth made by this plot in any one year since planting in 1924. This growth is representative of many of the outlying ponderosa pine plantations in 1933.

Norway pine Plot No. 20, though having a somewhat heavier infestation in 1932 than in 1931, maintained the excellent average height growth of 15 inches in the spring of 1933. The heavy damage to leaders the past season may lower this average in 1934. Many Norway pine trees were destroyed by winter-kill in the winter of 1932-33, but fortunately for these records this plot of trees, below a ridge on a north slope, was not seriously affected. Four trees in the plot, however, had from one-half to two-thirds of the crown killed, which otherwise would have given the plot an increased average height of about 1½ inches. Norway pine was apparently the only tree species damaged by winter-kill.

The remaining two ponderosa pine plots show a small increase in height growth for 1933, in spite of damage to the tips of most leaders

the previous season, and this is accounted for by the more favorable 1933 growing season.

Parasitism of Rhyacionia frustrana bushnelli

The usual procedure was followed in determining the amount of parasitism for the first generation of R. bushnelli--by collecting infested tips just prior to the emergence of the first moths in late June and recording the emergence of all insects from cages in the laboratory during the next six weeks. A total of 2,400 ponderosa pine tips were collected at eight separate collection plots in different parts of the plantations. The native parasites as usual accounted for only a small amount of parasitism, while the introduced parasite, Campoplex frustranae, was the one important species wherever parasitism was high. From 81 to 97% of all parasite specimens reared were Campoplex in the five plots showing the greatest percent of parasitism.

The average parasitism for all plots in 1933 was 42%, a decrease from the 49% recorded in 1932. (Some of the 1932 figures have been slightly revised from last year's report). However, parasitism did not decrease in all parts of the plantations. In three plots roughly within 1½ miles of the nursery, where Rhyacionia frustrana bushnelli is scarce and R. neomexicana is abundant, parasitism of bushnelli showed an average increase from 20% in 1932 to 29% in 1933. On the other hand, in the more distant plots approximately from 2½ to 4 miles from the nursery, where bushnelli is the more important species, parasitism remained higher than in the above area but showed a decrease from 62% in 1932 to 48% in 1933, as an average for five plots. A plot

near Camp 3, adjacent to Tip Plot No. 1, shown in Table I, had the greatest loss in parasitism, dropping from 79% in 1932 to 38% in 1933, accounting for the heavy infestation by second generation *bushnelli* moths.

The Campoplex parasite has been fluctuating in abundance in these outlying plantations from year to year, showing a high percent of parasitism one season but usually dropping off by the next year. The parasite here has failed to maintain a high percent of parasitism for two or more years at a time, as occurred in the plantations nearer the nursery where it was first liberated in 1925 and reached its peak in 1929 and 1930. Parasite and tree plot records had previously indicated that two years of heavy parasitism were necessary to reduce the number of leaders infested by *bushnelli* to a point where a marked increase in height growth of the trees would result. However, the last two years' data for Tip Plot No. 1 show that with parasitism causing a considerable reduction in tip moth infestation for one year, followed by a good growing season, the trees are capable of putting on a very good growth. This of course refers to areas where the original tip moth, *Rhyacionia frustrana bushnelli*, is the principal species, for it is probable that both parasitism and rate of growth will be interrupted as *R. neomexicana* becomes the more abundant species.

Rhyacionia neomexicana Infestation

In late June counts were made of the percent of leaders infested by *R. neomexicana*, and the number of larvae per leader, in ponderosa pine plantations above Block IV of the nursery, near the north edge of

the plantations and at half-mile intervals to the southwest. The trees examined at these points were of comparable age, having been planted in 1913, 1914, and 1915. Table II gives a comparison of these records with the two preceding years. A total of 300 leaders were examined in 1931, 200 in 1932, and 100 at each place in 1933.

TABLE II
PERCENT OF PONDEROSA PINE LEADERS
INFESTED BY *RHYACIONIA NEOMEXICANA*, AND THE
AVERAGE NUMBER OF LARVAE PER INFESTED LEADER IN PLANTATIONS ABOVE
THE NURSERY AND AT HALF-MILE INTERVALS TO THE SOUTHWEST, 1931 - 1933.

	1931	1932	1933
Hill above nursery			
% leaders infested	75	93	87
No. larvae per leader	4.8	6.0	4.6
½ mile to southwest			
% leaders infested	38	79	88
No. larvae per leader	2.2	4.0	5.4
1 mile to southwest			
% leaders infested	--	19	45
No. larvae per leader	--	1.9	2.2
1½ miles to southwest			
% leaders infested	--	--	61
No. larvae per leader	--	--	2.4

The records in Table II show that in the last few years the infestation decreased with distance from the north side of the planted area, near the nursery. It is evident also that this moth is spreading and increasing rapidly in the more recent areas. On the hill above the nursery, in the 1913 planting of ponderosa pine, a maximum infestation was attained in 1932, with a slight decrease in 1933; while all other plots show an increase in 1933 and will doubtless continue to build up to at least this maximum. The amount of infestation by the first generation of *R. bushnelli* was recorded for these same leaders in 1933.

This moth increased in abundance with distance from the nursery, the opposite from R. neomexicana, the infestation varying from 8% of the leaders infested near the nursery to 23% infested at a distance of 1½ miles.

In the plot one mile southwest of the nursery there was less infestation by neomexicana than at 1½ miles, and it has been observed that in this vicinity, north of the Halsey-Plantation road about due north of the lookout tower, the trees have been making better growth than in most other plantations of comparable age. However, the damage is now increasing rapidly in this particular area. Rhyacionia neomexicana is now seriously injuring all of the older plantations which extend for 1¼ miles south of the nursery and for a greater distance to the southwest and west. The infestation is also becoming noticeable at least 2½ miles to the west, beyond Camp 2. It appears that in a few years the entire planted area will be affected by this moth, except for the youngest plantations where the infestation will build up gradually during the first four or five years following planting.

The tree species most susceptible to damage by neomexicana, which is also true of the other tip moth, is ponderosa pine, and Norway pine will doubtless prove to be equally susceptible when the infestation becomes heavy in these plantations. Jack pine and Scotch pine are damaged to a lesser extent and recover from the injury better. Austrian pine again is apparently only lightly attacked.

Parasitism of *Rhyacionia neomexicana*

As previously stated, the introduced parasite has no influence on *R. neomexicana*. Many of the native parasites found attacking *R. bushnelli* also attack *neomexicana*, but the percent of parasitism is low. One new parasite, *Lissonota* n. sp., has been reared from *neomexicana*, but apparently does not develop in *bushnelli*, probably because of its larger size. This parasite destroys the host larva after it has spun its cocoon; spins its own cocoon within that of the host, where it passes the winter.

The most effective parasite in 1933 was the minute egg parasite, *Trichogramma minutum* Riley, which is known to attack the eggs of a great many moths. Of 430 *neomexicana* eggs collected in the field at intervals between April 28 and May 30, a total of 32% had been parasitized. However, this was not sufficient to prevent serious damage by the larvae from unparasitized eggs. The egg parasite was attacking the host eggs as early as April 28. The adult parasites did not start emerging until six days after the first tip moth eggs started hatching, emergence from the field-collected eggs occurring between May 24 and June 7.

Rhyacionia neomexicana Life History Notes

With early spring work in the Nebraska National Forest in 1933 it was possible to study the early seasonal history of *R. neomexicana*. When the first field examination was made on April 9 it was found that the earliest moths had already started to emerge. Four moths collected on that day were all males which doubtless emerge on the average shortly

before the females. General emergence did not take place, however, until later in the month, due to periods of cool weather, and the peak of emergence occurred approximately during the last ten days in April and continued into May. In the late afternoon of April 22 many moths were found on the lower bole of ponderosa pine trees, some with the wings not yet fully expanded. These moths had apparently just emerged from their cocoons and crawled up the bole.

From data previously secured on the original tip moth, it appears that the first generation of <u>bushnelli</u> and the single generation of <u>neomexicana</u> emerge at about the same time in the spring; the eggs hatch and the larvae are working in the tips during the same period, though the larvae of <u>neomexicana</u> feed longer, leaving the tips in late June and during July when <u>bushnelli</u> is pupating and adults of the second generation are emerging.

Cocoons of <u>neomexicana</u> were commonly found in bark crevices at the base of infested trees, usually at the ground line below the litter. It appears that this is the normal place for the larvae to spin up, especially on trees more than several inches in diameter where bark crevices offer protection. In some cases the larvae had eaten small holes in the thick basal bark at the ground line, where cocoons were constructed.

It is the habit of the smaller <u>bushnelli</u> larvae to spin their cocoons scattered in the litter or just below the surface of the soil, and none of the cocoons of this species were found on the base of the trees, though it is possible that they occasionally are placed there.

It appeared that the habit of the two species in leaving the tips differed, neomexicana probably crawling down the bole, the second generation bushnelli dropping from the tips when the larvae were mature--the first generation of bushnelli pupates in the tips. To demonstrate this, eight infested trees from 4 to 7 inches in diameter at the base were banded with tanglefoot about a foot above the ground in early July. Screen covered with tanglefoot was placed under the crown of two smaller trees, to catch any larvae dropping from the tips. Nearly every morning for the next three weeks several neomexicana larvae were found on the bole of some of the trees above the bands. Only three larvae were caught on the screens, and two of these were sickly and had apparently fallen from the tips. The migration from the tips down the bole took place during the night; usually no larvae could be found during the day but were always present the next morning.

In August, when the second generation bushnelli larvae began leaving the tips, seven small infested trees with basal diameters from 3 to 4 inches were banded with tanglefoot near the base. No larvae were found on the bole of these trees, indicating that they must have dropped from the tips, spinning their cocoons in the litter and soil beneath the crown.

Adult Rhyacionia neomexicana moths were collected in the field in late April and early May, a few also being reared from collected pupae, and were kept in the laboratory in vials containing several pine needles. Eggs were readily obtained in this manner where fertile

females had been taken. Some of the data on the life history of this insect are summarized below.

Adults lived without food in the laboratory for periods varying from 1 to 43 days. Infertile females lived the longest, several for periods from 36 to 43 days; the longest period for fertile females depositing eggs was 24 days; longest period for male moths was 25 days. These maximum records were from specimens taken on April 22.

Fertile eggs were deposited between April 22 and May 20 in the laboratory, but egg laying probably starts somewhat earlier in the field on a small scale. One female laid eggs over a period of 23 days.

Greatest number of eggs laid by a single female was 177.

Some of the infertile females, reared from pupae or collected on the base of trees immediately after emerging, deposited eggs, but these failed to hatch.

The first eggs started hatching in the laboratory on May 18, and hatching was completed on June 2. Early hatching was probably delayed a few days because of cool weather the first two weeks in May, and in more normal years hatching very likely starts at least by May 15.

The incubation period for <u>neomexicana</u> eggs varied from 10 to 27 days. Eggs laid in late April required from 3 to nearly 4 weeks to hatch, while those laid during warm weather after the middle of May hatched in less than 2 weeks.

Under natural conditions in the field the eggs are deposited in groups of from 2 to 19 eggs, usually 10 or less in a group, placed in one or two rows on the inner surface of the needles a half inch or less

above the bundle sheath. No eggs were found on the shoots, though it is possible that occasionally some are placed there.

In the field a few empty tips were found on June 24, and the following day a number of larvae were found starting cocoons at the base of trees. However, some larvae continued to work in tips until the last of July.

A fresh pupa was found on July 5. Mature larvae taken from the bole of tanglefoot-banded trees, after leaving the tips, spun cocoons and transformed to pupae within from 9 to 12 days.

Seasonal History of *Rhyacionia neomexicana*

From the above observations the seasonal history of *R. neomexicana* in the Nebraska National Forest can be briefly summarized as follows: A single generation occurs annually. The adult moths emerge from about the first of April to early in May, with the peak of emergence occurring in late April in normal years. The most active period of the day for the adults is in the evening just prior to and during dusk; no activity was observed when temperatures were below 50° F. The eggs are deposited in groups of from 2 to 10, occasionally as many as 19, placed in one or two rows on the inner surface of the needles just above the bundle sheath. The incubation period varies from 10 to 27 days, depending on temperature conditions. Eggs begin hatching about the middle of May in normal years, or a few days later when early May weather has been cool, and hatching is about complete by the first of June. Many of the young larvae bore into the base of the developing needles before entering the shoot. The new shoot is usually attacked at the apex, but in some instances the larvae start from 1 to 3 inches below the tip, working

down through the stem as they develop. Most of the shoots are fully elongated before serious injury occurs; however, full growth may be prevented in slow-developing adventitious shoots. The amount of injury to individual shoots depends on the number of larvae present. The early larvae are full grown and begin leaving the tips in late June; late larvae may remain in the tips until the last of July. The mature larvae crawl down the bole of the tree and spin their cocoons in bark crevices at the ground line below the litter, transforming to pupae in about 10 days. The remainder of the summer and the winter is passed in the pupal stage; adults again emerging the following spring.

DIPPING *RHYACIONIA NEOMEXICANA* EGGS

Experiments several years ago had shown that a 1% solution of "Volck Concentrate", a white oil emulsion, when used as a dip caused a complete mortality to the eggs of *R. bushnelli*; in fact, a 0.5% solution gave a complete kill for a smaller number of eggs tested at this strength. Consequently the 1% solution was recommended for dipping nursery stock shipped in the spring to points outside the forest, to prevent the distribution of the moth in the egg stage.

With the increased abundance of the more recent tip moth, *Rhyacionia neomexicana*, it was essential that this insecticide should be tested on the eggs of this species. This was carried out in the spring of 1933. A total of 464 eggs in different stages of development were dippedin a 1% solution of Volck Concentrate on May 18. Only 74% of the eggs were killed. The mortality, however, varied with the age or degree

of development of the eggs, being greatest in the more recently laid eggs. Averaged by weekly periods as to degree of development at the time of dipping, the eggs showed the following mortality:

151 eggs laid	April 24 to 30;	85% developed;	mortality	46%
198 " "	May 1 to 7;	75% "	"	86%
87 " "	May 8 to 14;	50% "	"	89%
28 " "	May 15 to 18;	20% "	"	99.6%

Untreated eggs from the same and other moths showed an average normal mortality of only 8%.

A smaller number of eggs, totaling 79, were dipped in a 0.5% solution at the same time, and a mortality of 99% was recorded. This is not very consistent with the lighter mortality for the stronger solution of 1%, but this is partly accounted for by the fact that the oldest group of eggs was not represented, and the sample was small.

It is apparent that 1% Volck Concentrate as a dip will not kill all neomexicana eggs, particularly where they are beyond the early stages of development. However, since most of the dipping of nursery stock is done in April when only the early eggs are present it is likely that the treatment would be fairly effective. By the time that it became apparent that neomexicana eggs were much more resistant than those of bushnelli, the Nebraska work had been discontinued for a period and there was no opportunity to continue the experiments with stronger solutions. It had been anticipated that since a 0.5% solution would kill eggs of the latter species, twice this strength or a 1% solution would be sufficient for the eggs of neomexicana. It is likely that a 2% solution

of Volck Concentrate will be about as efficient a dip, and at the same time as cheap, as would be found, and this strength, adding two parts of Volck Concentrate to 100 parts of water for the dipping solution, was recommended to the Forest Service this spring and put into use. The 2% solution should be safe to use on transplant stock, since as high as a 3% mixture had previously been tested on 2-0 stock without injury to the trees. Furthermore, 2% solutions have been used on trees in the field in both spring and summer with no evidence of foliage burning.

FIELD SPRAYING FOR EGGS OF <u>RHYACIONIA NEOMEXICANA</u>

On May 13 and 14, 1933, a few days prior to the hatching of the first eggs of <u>R. neomexicana</u>, 50 trees in a 1913 planting of ponderosa pine were sprayed with a 2% solution of Volck Concentrate, using a three gallon hand pressure sprayer. A majority of the eggs had been deposited on the needles at this time, although a few were doubtless laid subsequent to the spraying. Later in the season the number of infested leaders and all infested lateral tips were counted on the sprayed trees and on 50 unsprayed trees adjacent for comparison. The sprayed trees averaged 72 inches in height; the unsprayed trees averaged 73 inches. The counts showed the following:

44 leaders infested on the unsprayed trees.
19 " " " " sprayed trees.
A reduction of 57% in the number of leaders infested.

2185 lateral tips infested on the unsprayed trees.
813 " " " " " sprayed trees.
A reduction of 63% in the number of lateral tips infested.

The other moth, *R. bushnelli*, was very scarce in this area; however, its eggs would be similarly affected by the spray.

It is apparent that a considerable reduction in the amount of tip moth infestation can be effected by spraying about the middle of May for the egg stage. It is possible that the cool weather the first two weeks in May, delaying hatching until several days after the spray was applied, made the one application somewhat more efficient than might be found in other years if applied on the same date. A more effective method would be to apply two sprays, the first around May 10, the second about 10 days later, before any late eggs deposited after the first application should hatch. This method of control has particular application in small private plantations and windbreaks, and could undoubtedly be used with good results if carried out each spring, destroying many of the eggs of *neomexicana* and the first generation eggs of *bushnelli*. Summer spraying for the second generation eggs of *bushnelli* requires three applications of the 2% Volck Concentrate solution at six-day intervals for good results, although two applications at ten-day intervals during the egg laying period gave a fair reduction in infestation where the trees were not too bushy.

Spring spraying with a power machine might be used in accessible and limited areas of plantations in the forest for *neomexicana*. An increase in height growth should result the year following spraying, and two or more years application should accelerate height growth considerably. This of course would not prevent re-infestation when spraying was discontinued. One difficulty with large areas would be the limited period

for spraying. Spraying might be continued for 10 days in mid-May, but where only one application was used the trees treated in the early and late part of this period would doubtless show less control than is indicated in the above experiments.

THE PITCH MOTH, DIORYCTRIA PONDEROSAE DYAR

A few additional life-history notes on the pitch moth were obtained in August and September, 1933, to supplement those presented in the report for 1932. Adult moths were reared from pupae collected in the field and held in screen cages outside and in the laboratory for mating; the females then being placed in glass jars with pieces of green and dry bark pinned together as a place for oviposition. The eggs were always placed in the narrowest possible space between these pieces of bark or under bark scales when these were present. The following notes briefly summarize some of the data recorded:

The average length of life for 44 moths held in the cages and glass jars, with only water occasionally supplied, was 15.6 days, varying from 3 to 28 days for individual moths. Average for the males was nearly two days longer than for females.

Egg laying began from 2 to 11 days after mating--in the field it is probably within several days at the least.

Individual females deposited eggs over periods varying from 7 to 21 days, and in the laboratory the last eggs were laid on September 11. In the field the earliest eggs are probably deposited by late July, indicating a laying period for the species of six to seven weeks.

The greatest number of eggs obtained from a single female was 125.

The incubation period varied from 8 to 25 days, depending on temperature conditions. In 1930 an egg collected in the field on September 11 required 28 days to hatch.

Most of the eggs are ovate in shape, some nearly elliptical, with the side attached to the bark usually slightly flattened. Average size of 60 eggs measured with a micrometer disc was 1 mm. long by 0.75 mm. in diameter.

The eggs are white at the time of laying, but gradually change to a distinctly red color within two or three days.

Newly hatched larvae placed on small green logs in the laboratory, in late August and early September, crawled under the bark scales and spun small hibernacula. When examined in early November, the larvae were still in these hibernacula, with no evidence of feeding. It appears that most, if not all, of the larvae pass the winter in the first instar in these larval cocoons, although it is possible that some of the earliest larvae feed for a time in late summer and early fall.

Spraying pitch moth attacks

Orthene (orthodichlorobenzene) was more thoroughly tested as a spray against the larvae and pupae of the pitch moth in late June and July, 1933, using undiluted Orthene and a dilution of 1 to 5 or a 16.6% solution of Orthene. The pure Orthene this year caused a slight amount of cambium injury, but there was no evidence of this injury with the diluted material. The spray was applied with a three-gallon hand pressure

tank, directing a small stream over the pitch mass and for 2 to 3 inches surrounding it on the bark, wetting the surface thoroughly. A total of 502 normal attacks on 100 trees, mostly Scotch pine and including a few Austrian pine, were sprayed. This does not include a number of doubtful attacks where the final examination showed little or no burrow, indicating that probably no larvae were present. The trees varied from 2 to 7 inches d.b.h., and the thin bark on these trees may be a factor in control of this type.

In attempting to dilute the Orthene it was found that it did not mix with water, and even with soapy water the liquids separated in a short time. The Orthene mixed readily with linseed oil or kerosene, and by adding soapy water an emulsion could be made, although it was not very stable. The linseed oil mixture appeared more stable than kerosene, and if well stirred remained without separating for several hours. The soap available for use was white P. & G. naphtha, with $\frac{1}{8}$ pound dissolved in 1 pint of water. Adding more soap than that given below appeared to make the mixture less stable.

The formula used for the diluted spray was as follows:

4 parts Orthene
1 part linseed oil
$\frac{1}{4}$ part soap
18 $\frac{3}{4}$ parts water

In spraying the tank was shaken at intervals to keep the solution well mixed. It is possible that Orthene diluted with only soapy water could be used if the liquid was kept well agitated or shaken before each application.

Trees sprayed in June were examined about a month later and the number of dead and live larvae or pupae and missing insects recorded. The examination of the July-sprayed trees was not completed until fall, when the empty pupal skins indicated the number of insects which survived. The undiluted Orthene was applied during three separate periods, the diluted solution during a single period; the data from the final examinations are summarized below. In collecting normal larvae and pupae during the season a record was kept of the number normally missing or lost without being observed when cutting into the burrows. About 20% of the insects were not found, and this percent is taken into consideration in estimating the probable effectiveness of the sprays.

Undiluted Orthene: June 20, when larvae about three quarters grown, sprayed 100 normal attacks. Final examination showed 27 dead insects (22 larvae, 5 pupae); 23 live insects; 50 insects missing. Or 54% of the recovered insects dead; and 77% dead or missing. Estimated control, 57% (discounting 20% of the insects as normally missing). Evidently a few of the insects were killed after pupating, which must not have occurred for at least 10 days after spraying.

Undiluted Orthene: July 13 and 14, when many of the larvae were mature and a few already in the pupal stage, sprayed 73 normal attacks. Final examination showed 13 dead insects (7 larvae, 6 pupae); 13 live insects; 47 insects missing. Or 50% of the recovered insects dead; 82% dead or missing. Estimated control, 62%.

Undiluted Orthene: July 24, when from 55 to 60% of the larvae had pupated, sprayed 129 normal attacks. Final examinations showed 40 dead insects (16 larvae; 24 pupae); 28 live insects; and 61 insects missing. Or 59% of the recovered insects dead; 78% dead or missing. Estimate control, 58%.

Orthene diluted 1 to 5 (16.6% solution): July 19, 20, and 21, when about 50% of the larvae had pupated, sprayed 200 normal attacks. Final examinations showed 27 dead insects (5 larvae, 22 pupae); 69 live insects; and 104 insects missing or not found. Or in percents: 28% of the recovered insects dead; 65% dead or missing. Estimated control, 45%.

Summary: The above data indicate that in thin-barked trees such as Scotch pine, from 2 to 7 inches d.b.h., undiluted Orthene destroyed on the average of about 60% of the larvae and pupae but caused a small amount of cambium injury in some cases. Orthene diluted 1 to 5, or a 16.6% solution, destroyed about 45% of the insects and caused no apparent injury to the cambium. The sprays affected both the larvae and pupae, and consequently could be used during June or as soon as the pitch masses are conspicuous, and during about the first three weeks in July, before many of the moths emerge. To prevent cambium injury it appears that the Orthene will have to be diluted, and it is possible that a 50% solution would be safe and give between 50 and 60% control. This dilution should be tested. It seems that such a spray could be used satisfactorily in the thinned and pruned plantations. The control obtained is about the same as secured by the winter cutting of heavily infested "brood" trees, and

spraying would save the cutting of additional trees. One gallon of Orthene covered about 100 attacks, applying the spray freely; the cost of the material is $4.50 for a ~~in~~ 5-gallon lot~~s~~.

In preliminary experiments in 1932 the undiluted Orthene caused no evident injury to the cambium. However, the spray was applied around the individual pitch masses with a small atomizer, and although the bark was wetted the liquid was probably much less freely applied than by using a direct stream in 1933. This may account for the lack of injury, or it is possible that the product is not standardized and may vary somewhat in strength from year to year. In 1932 no evidence of insect mortality was noted until three to four weeks after spraying; the last tree examined a month after showing 50% of the 10 larvae and pupae dead. It was assumed that the Orthene was slow acting, and this is perhaps true where the larval burrow is closed with fresh pitch and the material has to penetrate the bark. In 1933 it was observed that where the burrows were open or the material entered the larval tunnels the fumes took effect in a very short time--Orthene apparently acts as a fumigant and not as a contact insecticide, and several larvae sprayed directly with the liquid in the open failed to succumb. Several trees were watched for a short time following spraying and again examined after an hour or two. In one case where the pitch mass had dropped off leaving the hole from the burrow exposed, the larva crawled out onto the bark immediately after the undiluted Orthene was applied. Later this larva was found in the litter beneath the tree where it had fallen. In another case

a larva left its burrow 5 or 10 minutes from the time of application, falling to the ground 10 minutes later. In several other instances one or two larvae were found near the base of a tree an hour or two after spraying. Not all of these larvae were dead, however, as some of them placed in vials and left under the litter pupated, being mature at the time, and later produced moths. Several of the larvae did die without pupating, and in one case ants were observed attacking a larva on the ground. It is doubtful if any of these larvae after dropping from a tree would again locate it, and most of them would very likely be destroyed by ants and other predators. A majority of the larvae, however, remained in their burrows, and there was no evidence that they left the sprayed portion of the bark and attacked the tree at other points.

The Pitch Moth Infestation

Late in the season six of the permanent pitch moth plots were examined and the number of current attacks recorded. These included the four plots in Scotch pine, one in Austrain pine and one in ponderosa pine--the plots summarized in last year's report covering the pitch moth situation. All plots showed a natural reduction in infestation from that recorded in 1932. In the more heavily infested plots the reduction varied from 21 to 37%. In the lightly infested Scotch pine plots the reduction amounted to from 27 to 100%--one plot, No. 3A, with only 3 attacks in 1932 had no evidence of fresh work in 1933. The only control cutting during the winter had been in the

Austrian pine plot where five infested trees were removed, but this would not account for the 21% reduction from the previous year.

The exact cause of the reduction in infestation is uncertain, but it possibly was due to low temperatures during the winter of 1932-33. A minimum temperature of -22° F. was recorded in December, 1932; and minimums of -21, -25 and -23° for three consecutive days in February, 1933, with maximums for two of these days reaching only a -11 and -14°. In 1930 there was a similar drop in the infestation, and minimum temperatures of -23, -30 and -25° were recorded for three days in succession in January of that year. In 1929, when the infestation showed an increase, a minimum temperature of -27° occurred on one day only in February, and apparently this had little or no influence on the infestation. Temperatures of -20° have been recorded in other winters, followed by an apparently normal increase in the number of attacks. If freezing causes mortality to the young hibernating larvae under the bark scales, it appears that it must be due to very low extremes in temperature or low temperatures continuing for several days at a time.

With the pitch moth infestation reduced in Scotch and Austrian pine, the most seriously affected trees, by the winter control cutting operations in 1932 and the additional natural reduction in 1933, the situation is much improved. In fact the epidemic was lighter in 1933 than it had been for several years. A few trees, however, were found girdled during the season--mostly pruned trees where the larvae had destroyed the cambium between the pruning scars. Girdling of such

trees, nevertheless, is not as prevalent as that occurring several years ago before thinning and pruning was carried out and the heavily infested trees removed.

WHITE GRUB CONTROL EXPERIMENTS

In April, 1933, an experiment was started to test the effect of lead arsenate-treated soil on different species of pine transplants in Bessey Nursery in the Nebraska National Forest, in cooperation with Nurseryman Dayharsh. Since 1933 was the season for the second year grubs of Brood A, the most numerous brood, an attempt was also made to determine the effect of various dosages of lead arsenate on grubs added to the transplant beds. Soil was treated in Block III of the nursery for two adjacent beds, one to contain red cedar and different species of pine transplants; the second bed containing 2-1 ponderosa pine and 1-1 jack pine transplants, to be screened in by plots to a depth of 10 inches in the soil and grubs added in various numbers.

The nursery soil is sandy and would probably be classed as a light sandy loam about neutral in acidity. The beds are irrigated by flooding when needed, and the soil is never permitted to dry out; consequently it seems doubtful if the grubs would go very deep during the summer.

The beds were prepared on the following dates: April 24, 1933, the soil was plowed and harrowed. April 26, three plots were treated with powdered lead arsenate at the rate of 500 pounds, 1,000 pounds, and 1,500 pounds per acre respectively. The material was weighed out

and mixed with soil as an aid in broadcasting evenly over the surface, and following this the soil was disced two ways and harrowed, distributing the poison to a depth of 3 or 4 inches. On April 28 the trees were transplanted in the treated plots by the regular transplant crew, along with two check plots of the same species in untreated soil at each end of the beds. Regular stock, of the species listed in the table below, were used for transplanting, the experiment therefore dealing with 2-1 and 1-1 transplants. A total of 300 trees of each species and age, in 6 rows, were used in each of the treated plots, the tree species being alternated in 3-row lots to insure average soil conditions. The two untreated check plots contained 600 trees of each species and age. Table III shows the percent of mortality to the trees in the check plots compared to the treated plots, as recorded at the end of the season in October, 1933.

TABLE III
AVERAGE MORTALITY TO RED CEDAR AND PINE TRANSPLANTS
IN SOIL TREATED WITH 500, 1,000 and 1,500 POUNDS OF LEAD
ARSENATE PER ACRE AS COMPARED TO UNTREATED CHECK PLOTS

Age and species of transplant stock	% mortality in check plots	% mortality in plots treated with lead arsenate at rate of: 500# per acre	1000# per acre	1500# per acre
2-1 red cedar (*Juniperus virginiana*)	6.3	21.3	32.6	46.0
2-1 Austrian pine (*Pinus austriaca*)	12.0	49.7	66.3	70.0
2-1 ponderosa pine (*Pinus ponderosa*)	(41.8) 16.3*	61.0	59.0	73.0
1-1 ponderosa pine (*Pinus ponderosa*)	59.2	97.0	97.3	99.7
1-1 jack pine (*Pinus banksiana*)	62.0	99.0	100	100

*(One check plot of the 2-1 ponderosa pine had only a 12.3% mortality; the other 71.3% mortality, which was obviously far above normal and may have been due to poor planting of these particular rows or drying out of the roots before planting these last trees. Averaging the first check plot with an unaffected

plot in the grub bed adjacent gives a mortality of 16.3%, which compares more favorably with the nursery average.)

The data in Table III indicate that even with the lightest dosage of 500 pounds per acre the loss to 2-1 transplants was 3½ to 4 times the normal mortality. The stronger dosages show a proportionately greater loss in most cases. With the younger 1-1 transplants practically a complete mortality occurred. (The loss in the 1-1 check plots is considerably above the nursery average.)

It appears that tolerance to arsenic may be partly dependent on the age of the trees. From the limited literature on the subject it seems that arsenates are apt to cause much more damage in light soils than in heavy soils. The tolerance of plants in heavy soils may be due to certain minerals, or organic matter in virgin soils, preventing the reduction of the arsenates to more toxic compounds. The arsenic may also have an effect for two or more years after being applied.

In the treated plots some of the trees showed the new growth partially stunted. Upon digging trees in the 500-pound-per-acre plot it was noted that the root system had apparently been seriously affected and very few new lateral roots put on during the season. Cow peas and rye, used as a cover crop in the nursery, were planted on a strip of treated and untreated soil adjacent to the beds. Germination and growth were seriously retarded by the arsenic, the injury varying directly with the dosage. Very little survival was found in the 1,500-pound-per-acre plot, while a partial and stunted stand was produced in the 500-pound-per-acre plot, compared to the untreated stand.

No information was obtained on white grub mortality in the screened-in plots because the introduced grubs failed to survive. Most of the grubs, obtained during plowing, were added on May 10, with the remainder on May 17 and 22. They were placed in holes and slits between the rows, to a depth of two and three inches. With chilly weather the first half of May it is possible that the soil packed too solidly around the grubs before they became active. Possibly not enough soil was loosened where the grubs were introduced, or they may have better been added a little later in the spring. Only healthy appearing grubs were used.

It was apparent late in the season that the grubs had probably failed to survive, since in plots where 20 grubs per square yard had been added there was little or no evidence of injury to the trees. However, four of the twenty plots were dug to depths of 15, 18 and 20 inches in October, and the soil run through a screen. In three untreated plots, where a total of 70 second-year grubs had been introduced, only one was found, and in addition one first-year grub. In one plot treated with 500 pounds of lead arsenate per acre, where 40 grubs had been introduced, none were recovered, but since practically none had survived in the check plot this had no significance and the remaining grub plots were not dug.

From recent experiments, R. A. St. George, of the Division of Forest Insects, has evidence that about 400 pounds of lead arsenate will kill grubs in light, slightly acid soils in the Carolinas, and

apparently cause little damage to one-year seedlings of southern pine. It does not appear likely in Nebraska that seedlings of the species in use would stand this dosage, since the 500 pounds per acre killed practically all 1-1 stock in the experiments. The 2-1 transplants might tolerate 400 pounds per acre with only light injury; however, the 500 pound dosage proved too strong for practical use under Nebraska conditions. It appears that the margin between tolerance of the trees and toxic effect to the grubs may be very limited, and the use of lead arsenate in Bessey Nursery is questionable without additional experiments proving its safety.

THE GRASSHOPPER INFESTATION

Since 1929 grasshoppers have been particularly destructive in the young pine plantations, although this type of injury had been recorded in earlier years. Control in the younger and current plantings in the last three seasons has prevented a great amount of destruction.

With damage somewhat less in 1932 it was hoped that no control would be necessary in 1933. An attempt to get an estimate of the grasshopper population in early June, 1933, was not satisfactory, many of the insects still being very small and difficult to count in the heavy grass. In early July Ranger Rotty reported damage occurring, and an examination of 677 ponderosa pine planted in April showed about 5% girdled and an additional 22% of the small trees fed on in various degrees. Since heavy feeding was only starting, it was apparent that damage by the end of the season would far outweigh the cost of control.

The Forest Service immediately proceeded with control, poisoning the area covered by the current plantations. The total area treated, as recorded from the Ranger's report, was 850 acres. Although there was no opportunity to make extensive counts on the grasshopper kill obtained, the condition of the trees late in the season indicated that control was again satisfactory.

BARK BEETLES

A few scattered jack pine were noted fading in the spring of 1933, and a number of them were examined for bark beetles in early May. Some of the trees had no evidence of bark-beetle attacks; a few had *Dendroctonus valens* attacks in the base. Most of these trees had not been entirely girdled by the *valens* galleries, although the remaining portion of the base in some cases had been filled in by the small secondary beetle, *Hylurgops porosus*, apparently after the trees were dying. The ranger found a few additional *valens*-attacked jack pine during the season, and treated the basal infested portion. The same condition prevailed in most of these trees, the entire bole not always being girdled. It is still uncertain whether *Dendroctonus valens* is developing primary tendencies and attacking and killing a few healthy trees in the plantations or, as seems more likely from the above observations, attacking weakened trees which are dying without being completely girdled. It is possible that the dry seasons of 1931 and 1932 weakened many of these jack pine. The beetle had apparently not developed to any serious numbers during the season. When it is

considered that only a small number of these beetles would be required to kill trees of the size in the plantation, the importance of watching for any serious increase or tendency to attack and kill healthy trees becomes apparent.